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Property Evaluation of Hybrid Seashell/Snail Shell Filler Reinforced Unsaturated Polyester Composite In Comparison With Seashell and Snail Shell Filler Reinforced Unsaturated Polyester Composite

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----------ABSTRACT----------

This research is aimed at discovering filled polyester with desirable and superior properties using naturally occurring particulate: seashell, snail shell and hybrid (combination of seashell and snail shell). The mechanical (flexural,tensile,impact and hardness) and physical(water absorption) properties of sea shell, snail shell, and sea shell-snail shell-reinforced composites were investigated. The shells were ground and sieved using 250 microns hand sieve. The test specimens were prepared using polyester resin with different compositions and prepared in accordance with ASTM standard. From the result, hybrid sample of 30wt% reinforcement showed the highest resistance before shattering relative to other samples the flexural test was performed on, the surface hardness of the hybrid at 15wt% reinforcement was also greatly enhanced. Therefore for applications where flexibility is of top priority, hybrid reinforcement of 30wt% should be used in place of neat polyester. Snail shell sample of 5wt% reinforcement showed to absorb the highest amount of energy before shattering relative to other samples, for this, snail shell reinforcement of 5wt% can be used in place of pure polyester where impact strength is a major factor.

KEY WORDS: *Hybrid, sea shell, snail shell, unsaturated polyester, composite*

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I. INTRODUCTION:

Both thermoplastics and thermosets can reap the benefit of fibre reinforcement although they have developed in separate market sectors[1]. Of which unsaturated polyester is an example of these thermosets. Studies have been on-going on polymeric composites but only a few works has been done on unsaturated polyester composites here in Nigeria irrespective of her abundant natural resources. Sea shell as well as snail shell is considered as wastes here in Nigeria. That was what determined this research. In the work on the effect of clay addition on the mechanical properties of unsaturated polyester/glass fibre composite, the tensile strength, flexural strength, and flexural modulus of the composites were increased in the presence of clay [2]. Unsaturated polyester (UP) resins were filled with bentonites modified with silsesquioxanes; it was found that the mechanical properties of the cured resin improved [3]. In the tensile properties characterization of okra-woven fibre reinforced polyester composite, the specific tensile strength and modulus of both treated and untreated okra fibre-reinforced polyester composite were higher than pure polyester specimen [4]. Researchers have taken to the use of hybrid composites by combining different types of fibres in a common matrix[5]. In hybrid pineapple leaf and glass fibre reinforced polyester, thermal conductivity and thermal diffusivity were found to increase as the glass content was increased [6]. Glass fibres are the principal form of reinforcement used for plastics because they offer a good combination of strength, stiffness and price, the latest developments also include the use of hybrid systems to get a good balance of properties at an acceptable price [1]. A self-healing hybrid polymer composite consisting of jute and glass fiber was developed to eliminate delamination and to obtain lighter composites with lower maintenance costs[7]. In the evaluation of mechanical properties of bagasse-glass fibre reinforced composite, it was found that mixing bagasse fiber with glass fiber improved the modulus of elasticity and impact strength but there was a decrease in the ultimate strength and bending strength[8].

In the study of the mechanical properties of coir/glass hybrid fiber phenolic resin based composites, the coir-glass hybrid polyester composites were found to be promising candidates for structural applications where high strength and stiffness are required[9]. It is known that the mechanical properties of fibre reinforced composites among others depend to a large extent in the fibre content variations [10, 11, and 12]. In this research, there are some significant interests in order to characterize and investigate the properties of unsaturated polyester/filler composites which include tensile properties, flexural properties, water absorption properties, hardness properties. Due to the wide application of polymer composites, therefore it is highly encouraging to study on the utilization of local cheap renewable sources of fiber and fillers available in our country for the production of this polymer composite.

II. MATERIALS AND METHODS

(a) Collection and processing of snail and sea shells

The snail shells were obtained from the market in Bariga area of Lagos, while the sea shells were obtained from Kuramo beach Lagos, Nigeria.

The shells were cleaned and sun dried for three days before grinding. The shells were sieved with a hand sieve size of 250 microns in the Metallurgical and Materials Engineering laboratory of University of Lagos.

(b) Preparation of seashell, snail shell and hybrid-polyester composite

i.weighing of the unsaturated polyester resin:

The unsaturated polyester resin was weighed by placing a petridish on the electronic weighing machine and the particulate added gradually into the petridish until the desired weight of particulate necessary for a particular formulation was achieved. The process was repeated for other weight fractions of particulate needed. . Pouring of the polyester into the beaker is stopped when a 100g of polyester is reached. The beaker is removed from the weighing machine and is placed aside.

Weighing of the snail shell: The two particulate was weighed using an electronic weighing machine based on the weight percentage of the particulate to be added to the polyester resin. A petridish is placed on the electronic weighing machine and the particulates are added gradually into the petridish, the weight indication is observed as more particulate are continually added. Pouring of the particulate into the Petridis is stopped when the desired weight of particulate necessary for a particular formulation is achieved. The process is repeated for other weight fractions of particulate needed. The beaker is removed from the weighing machine and is placed aside.

Weighing of the catalyst Methyl ethyl ketone peroxide (MEKP); The catalyst (MEKP) was weighed using an electronic weighing machine. A beaker is place on the weighing machine and in it is placed a test tube the catalyst is added gradually into the test tube with the help of a syringe, the weight indication is observed as more drops of catalyst are continually added. Pouring of the catalyst into the test tube is stopped when a 1g of catalyst is obtained. The test tube is removed from the weighing machine and is placed aside.

Weighing of the Accelerator (Cobalt Naphthanate) : The Accelerator (Cobalt Naphthanate) was weighed using an electronic weighing machine, a beaker is placed on the weighing machine and in it is placed a test tube the accelerator is added gradually into the test tube with the help of a syringe, the weight indicator is observed as more drops of accelerator are continually added. Pouring of the accelerator into the test tube is stopped when a 0.5g of accelerator is obtained. The test tube is removed from the weighing machine and is placed aside

III. MIXING OF THE CONSTITUENTS:

In synthesizing the reinforced polyester composites, the mass of the polyester was varied with that of the reinforcement to give a total of 100grams (i.e. for every 100gram of 5wt% composition of reinforcement, there will be 95 grams of polyester and 5grams of reinforcement) this was done for particulate composition of (5wt%, 10wt%, 15wt%, 20wt%, 25wt%, 30wt%) and stirred manually with a glass rod and it is mixed intimately until a good mixture is obtained. Thereafter, 1g of catalyst was added and stirred for, after which 0.5g of accelerator was added and stirred.

IV. CASTING OF THE MIXTURE;

The mixture was poured into a mould already coated with paper tape and allowed to cure. This procedure is repeated for all samples produced with changes in the particulate percentage. After curing the samples were stripped from the mould.

(c) **Formulations of filler/polyester composite**

The formulations used are given below

Table 1. Formulation of sea shell filler/polyester composite

Specimen	Composition (g)			
	Particulate snail shell filler	unsaturated polyester	Methyl ethyl ketone peroxide (catalyst)	Cobalt naphthanate (accelerator)
A	5.0	95.0	1.0	0.5
B	10.0	90.0	1.0	0.5
C	15.0	85.0	1.0	0.5
D	20.0	80.0	1.0	0.5
E	25.0	75.0	1.0	0.5
F	30.0	70.0	1.0	0.5
Control	0.0	100.0	1.0	0.5

Table 2 Formulation of snail shell filler/polyester composite

Specimen	Composition (g)			
	Particulate snail shell filler	Unsaturated polyester	Methyl ethyl ketone peroxide (catalyst)	Cobalt naphthanate (accelerator)
A	5.0	95.0	1.0	0.5
B	10.0	90.0	1.0	0.5
C	15.0	85.0	1.0	0.5
D	20.0	80.0	1.0	0.5
E	25.0	75.0	1.0	0.5
F	30.0	70.0	1.0	0.5
Control	0.0	100.0	1.0	0.5

Table 3 Formulation of hybrid filler/polyester composite

Specimen	Composition (g)			
	Particulate snail shell filler	Unsaturated polyester	Methyl ethyl ketone peroxide (catalyst)	Cobalt naphthanate (accelerator)
A	5.0	95.0	1.0	0.5
B	10.0	90.0	1.0	0.5
C	15.0	85.0	1.0	0.5
D	20.0	80.0	1.0	0.5
E	25.0	75.0	1.0	0.5
F	30.0	70.0	1.0	0.5
Control	0.0	100.0	1.0	0.5

Fig 1sea shell used

Fig 2 snail shell used

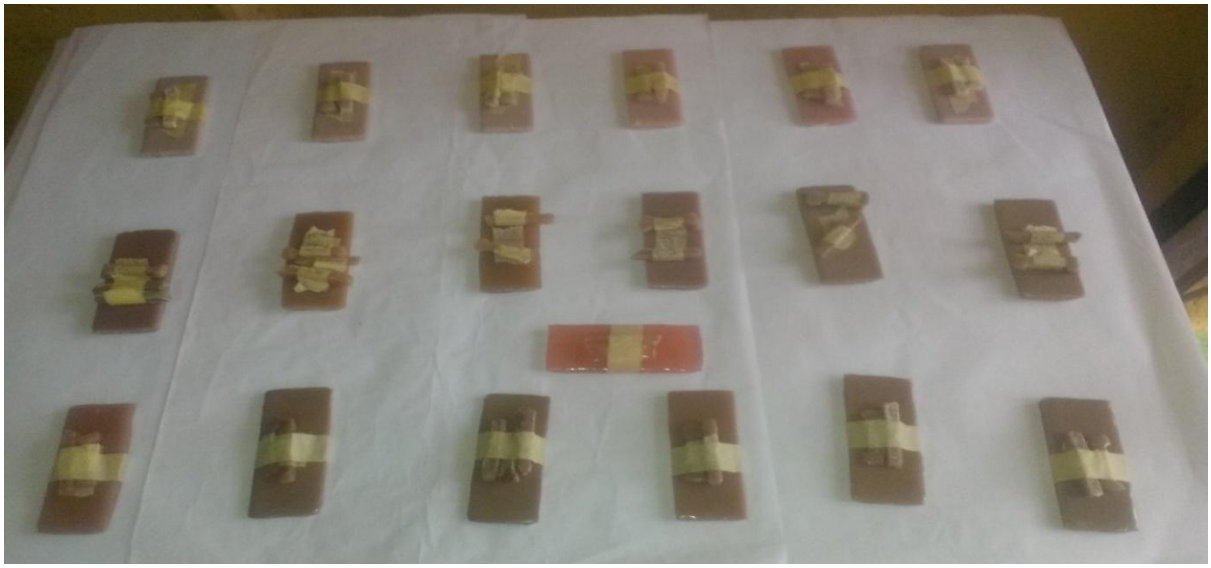

Fig 3 cast samples of sea shell, snail shell and hybrid

(d) characterization of the samples

(i) **Tensile test :** The tensile testing was performed using an Instron universal testing machine operated at a cross head speed of 10mm/min. The tensile test specimen preparation and testing procedures were conducted in accordance with ASTM standard D412 (ASTM D412 1983), using dumbbell test piece. Each tensile specimen is positioned in the instron universal tester and then subjected to tensile load, as the specimen stretches the computer generates graph as well as all the desired parameters until the specimen fractures. A graph of load versus extension is plotted automatically by the tester and various property of the specimen determined are; tensile strength, tensile strain, modulus, tensile strain at break e.t.c.

(ii) Flexural test : Three point flexural testing were conducted using testometric testing machine with serial number 25257 and capacity M500-25KN at Federal institute of Industrial Research, Oshodi (FIIRO).
The flexural test was carried according to ASTM D 7264 at a cross-head speed of 20mm/min, maintaining a span of 100mm. This test was conducted at room temperature. The flexural test specimens were of 120 X 50 X 10 mm. The testometric machine was used to carry out the three point bending flexural test on the polymeric material composite at different filler content at 0, 5, 10, 15, 20, 25 and 30 wt% of filler content.

(iii) Water absorption test : The samples were cut in dimension; their initial weights were taken with the aid of an electronic weighing scale. Each of the samples was immersed in a beaker containing water and the new weights of the samples were recorded.
Water absorption which is a measure of material ability to absorb moisture (water) was obtained by immersing the specimen for 168 hours in water. After immersion, the surfaces of the specimens were cleaned dry and weighed immediately to measure their wet weight. The increase in weight is recorded as percentage gained and is expressed by;

$$\frac{final\ weight - initial\ weight}{initial\ weight} \times 100\%$$

(iv) Hardness test : The hardness test was carried out using Brinell's hardness testing machine in Obafemi Awolowo University Ife, Osun State, Nigeria. The hardness test was carried out on the polymeric material composite at different filler content at (0, 5, 10, 15, 20, 25 and 30) wt% of filler content.

(v) Impact test : This test was carried out also at the Obafemi Awolowo University Ife. Impact test is a standard method of determining the impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact energy is determined. A notched sample is used to determine impact energy and notch sensitivity.

V. RESULTS AND DISCUSSIONS

Table 4 Result of mechanical tests on 0wt% snail shell, sea shell and hybrid reinforcement.

Reinforcement	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	30.85	927.28	3.81	24.87	262.05	0.0395	0.885
Sea shell	30.85	927.28	3.81	24.87	262.05	0.0395	0.885
Hybrid	30.85	927.28	3.81	24.87	262.05	0.0395	0.885

Table5 Result of mechanical tests on 5wt% snail shell, sea shell and hybrid reinforcement.

Reinforcement	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	25.72	770.30	5.58	20.21	205.95	0.0383	1.096
Sea shell	27.67	814.28	4.35	22.55	101.20	0.0194	0.964
Hybrid	27.13	931.55	3.81	13.44	44.95	0.0189	1.709

Table 6 Result of mechanical tests on 10wt% snail shell, sea shell and hybrid reinforcement.

Reinforcements	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	28.35	1030.40	3.67	23.20	157.64	0.0203	1.149
Sea shell	35.65	1435.20	5.17	25.92	90.70	0.0147	1.130

Hybrid	20.38	698.68	4.76	24.72	71.13	0.0136	2.026

Table7 Result of mechanical tests on 15wt% snail shell, sea shell and hybrid reinforcement.

Reinforcement	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	26.05	1445.10	3.54	20.32	67.54	0.0111	0.891
Sea shell	24.88	1492.90	4.76	20.65	169.38	0.0283	0.908
Hybrid	30.97	1403.50	4.69	29.88	26.48	0.0083	1.014

Table8 Result of mechanical tests on 20wt% snail shell, sea shell and hybrid reinforcement.

Reinforcement	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	22.24	985.16	3.46	21.36	91.19	0.0131	2.242
Sea shell	26.38	1295.40	4.42	21.33	81.74	0.0081	0.950
Hybrid	36.03	1730.80	4.49	29.69	53.75	0.0136	1.066

Table 9 Result of mechanical tests on 25wt% snail shell, sea shell and hybrid reinforcement.

Reinforcement	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	18.43	1659.30	3.24	21.22	105.43	0.0153	0.778
Sea shell	27.17	1365.00	4.08	20.21	160.94	0.0136	0.829
Hybrid	31.18	1661.10	3.81	19.99	97.15	0.0122	1.002

Table10 Result of mechanical tests on 30wt% snail shell, sea shell and hybrid reinforcement.

Reinforcement	Bending strength at peak/ break (MPa)	Bending modulus (MPa)	Impact strength (Joules)	Brinell Hardness (BHN)	Ultimate Tensile Strength (MPa)	Tensile strain (mm/mm)	Percentage water absorption
Snail shell	17.32	866.78	4.35	23.47	77.45	0.0178	0.715
Sea shell	20.77	1077.10	3.54	20.10	112.56	0.0131	1.211
Hybrid	38.37	2334.90	3.54	19.87	110.57	0.0161	0.896

(a) Flexural properties

(i) Bending strength at peak /break

From figure 4 it was observed that bending strength at peak/break for all the three reinforcements fell from 0-5wt%, but as for the snail shell reinforcement, it rose at 10wt% after which it continually dropped because the increase in weight percentage of filler likely reduced the deformability of the matrix, and in turn reducing the ductility of the composite thereby forming a non-too strong structure. The reduction in the bending strength at peak of the snail shell reinforcements could be as a result of controlled mobility of matrix by filler particles. As the amount of reinforcement increases the total surface area available for matrix-filler interaction decreases.

The sea shell however shows a high bending strength at 10wt% after which the value continually undulates. The hybrid actually shows the highest bending strength at 30wt% reinforcement.

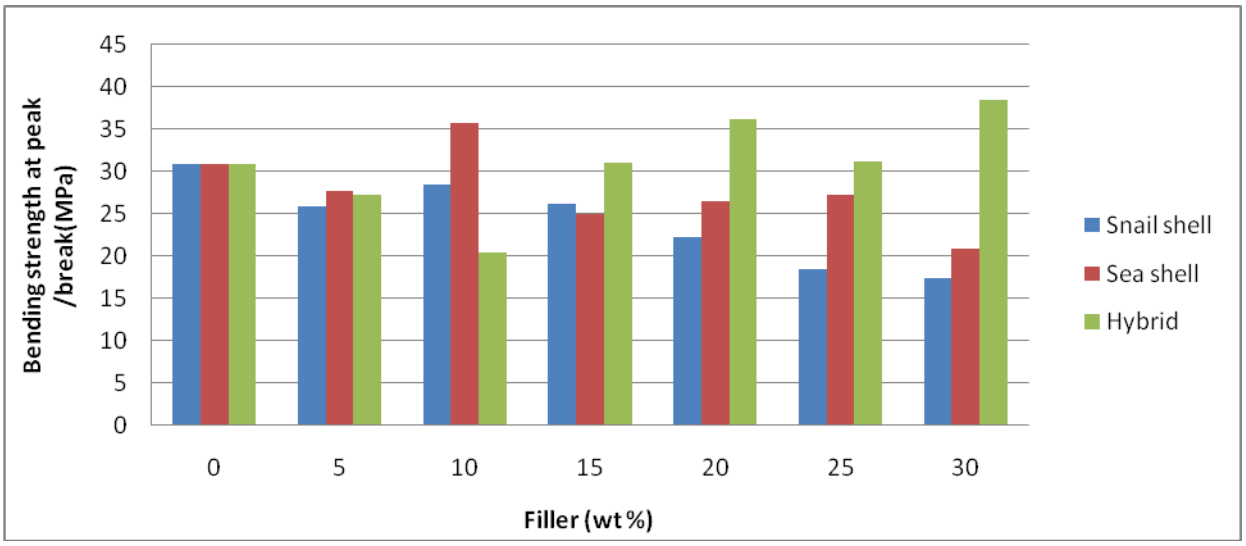

Fig 4 Chart of bending strength against filler concentration

(ii) Bending Modulus

Figure 5 shows the bending modulus of all of the three reinforcements with the snail shell reinforcement showing an undulating/sinosoidal patten. However, the hybrid reinforcement shows a steady increase in bending strength after dropping between 5wt% and 10wt%. The highest bending modulus is recorded at 30wt% which is the hybrid sample.

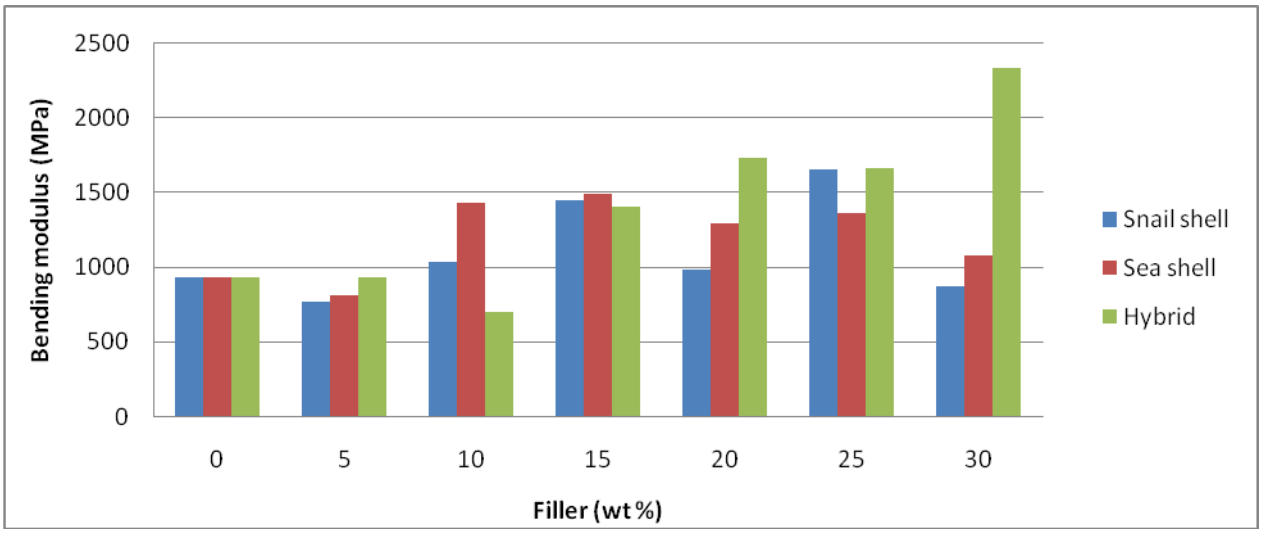

Fig 5 Chart of bending modulus against filler concentration

(b) Impact test : The figure below shows the amount of energy the samples can absorb prior to fracture. It was observed that the sea shell and hybrid samples can only absorb maximum energy at 10wt% filler concentration. However, the maximum amount of energy absorbed was by the snail shell at 5wt% reinforcement. The impact strength decreases as the filler content increases.The elasticity of the material is reduced as the filler increases and this reduces the deformability and the ability of the material to absorb energy is also reduced .There is no explanation to this but it could be attributed to discontinuity of matrix phase in the composite.

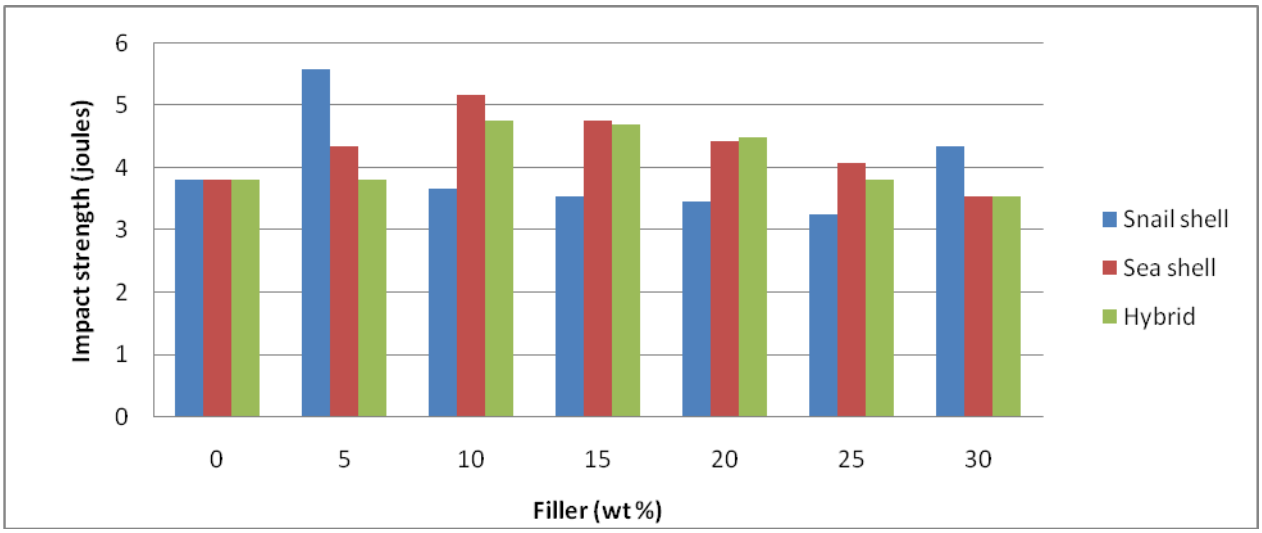

Fig6 Chart of Impact strength against filler concentration

(c) Hardness test : From the figure below, it was noticed that the highest hardness was exhibited by hybrid reinforcement at 15wt% while other reinforcements such as snail shell and sea shell both showed undulating patterns. The unpredictable pattern of the hardness could be as a result of poor interfacial bonding between the fillers and polyester matrix.

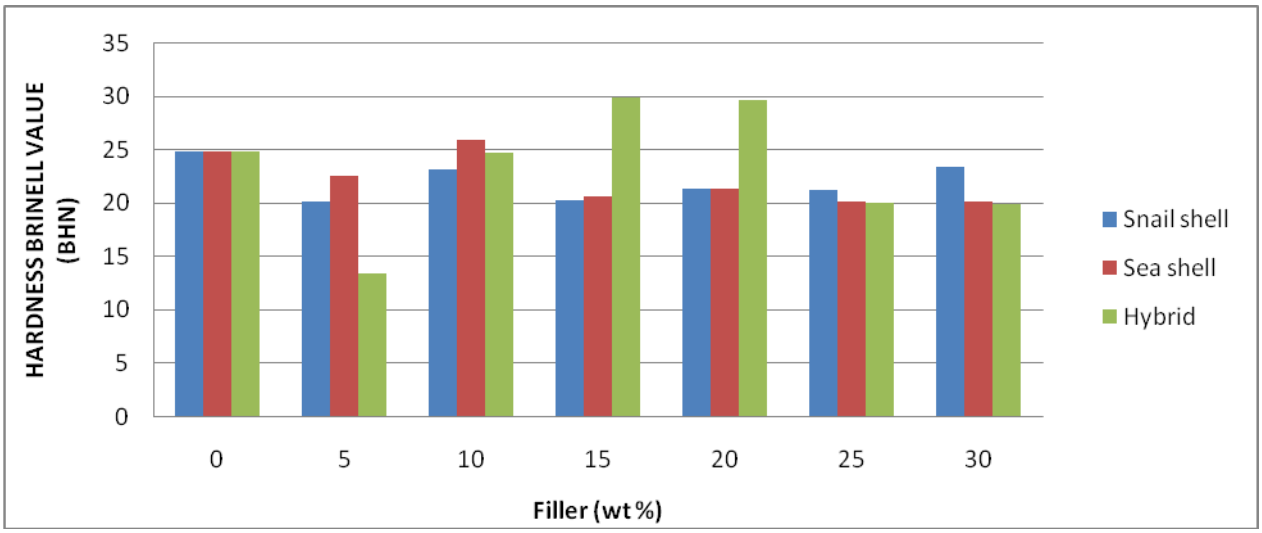

Fig 7 Chart of Brinell hardness against filler concentration

(d)Tensile Test

(i) Ultimate Tensile Strength (UTS): The figure below shows the graph of ultimate tensile strength of all composite samples against their corresponding percentage reinforcement. It was observed that the snail shell composite at 5wt% filler concentration shows the highest tensile strength, while the hybrid sample of 15wt% filler concentration showed the least ultimate tensile strength, while the sea shell showed its maximum UTS at 15wt% filler concentration. The ultimate strength of a composite depends on the weakest fracture path throughout the material. Hard particles affect the strength in two ways. One is the weakening effect due to the stress concentration they cause, and another is the reinforcing effect since they may serve as barriers to crack growth [13]. In this case the weakening effect is predominant and thus the composite strength is lower than the matrix; and in other cases, the reinforcing effect is more significant and then the composites will have strengths higher than the matrix.The better tensile strength at lower filler content most especially for snail and sea shell could be attributed to good interfacial bond, better dispersion of the reinforcement in the polyester resin matrix

and better wettability,. The lower tensile strength for all other filler content could be attributed to poor stress transfer between the particle-matrix interface which could be as a result of poor interfacial adhesion between the filler and the polyester matrix.

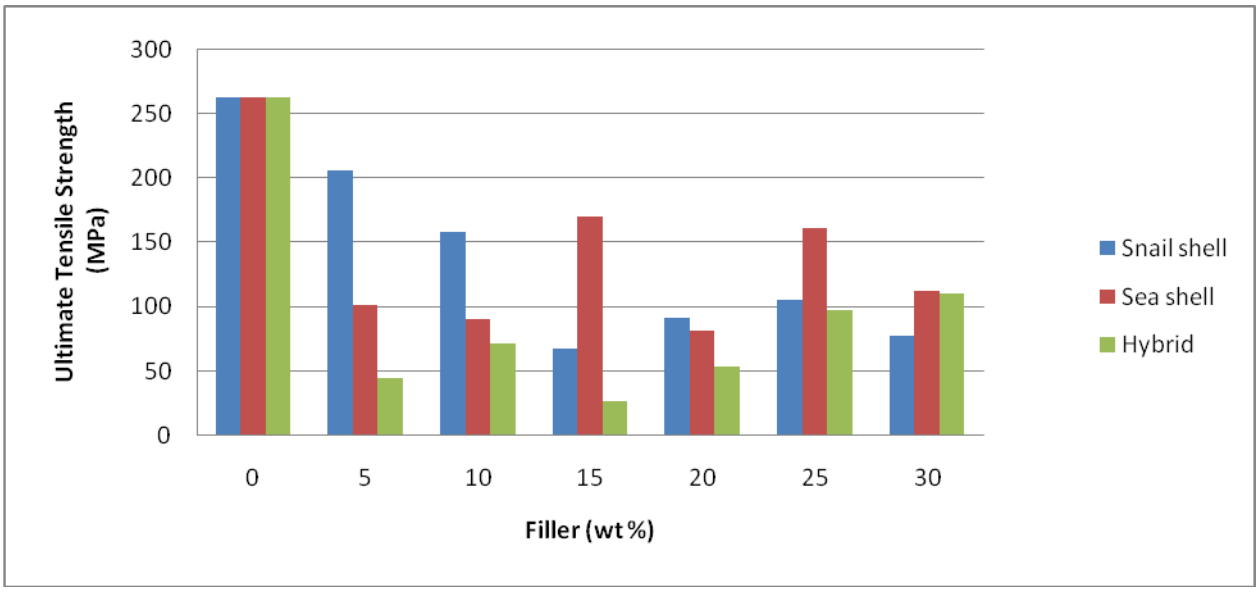

Fig 8 Chart of ultimate tensile strength against filler concentration

(ii) Tensile Strain at maximum load : Again here from the figure below, the Tensile strain at maximum load seems to follow a similar trend as that of the UTS because stress and strain have always shown to be proportional. Here, it is seen that the 5wt% snail shell reinforcement has the highest strain and also the 15wt% hybrid reinforcement showing the least strain, while the sea shell showed its maximum strain at 15wt% filler concentration. This graph shows that additional filler concentration to the 5wt% snail shell reinforcement and the 15wt % sea shell reinforcement will not improve the strain.

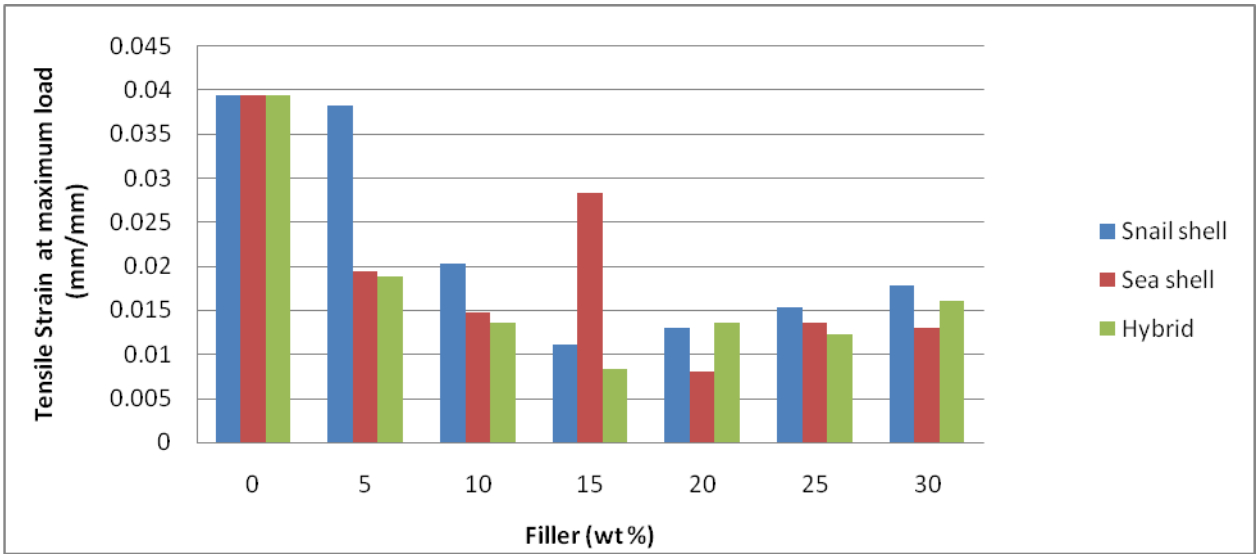

Fig 9 Chart of tensile strain against filler concentration

(e) Water Absorption Test : The percentage of water absorption for all the composites is shown in the figure 10 below. It can be seen that increasing the filler content, the water absorption becomes quite unpredictable although all the composites are shown to be hydrophilic. The poor wettability and interfacial adhesion between

the reinforcements and polyester resin are attributed to the hydrophilic nature of the fillers. This hydrophilicity is responsible for the higher percentage water uptake in the composites. In case of surface modified composites, the filler get masked with the unsaturated polyester resin in the laminate with the stronger adhesion resulting in greater hydrophobicity and less water absorption. As shown in the graph below, it is being noticed that the most hydrophilic of all is the 20wt% snail shell reinforcement, while the least hydrophilic of all is the 30wt% snail shell reinforcement.

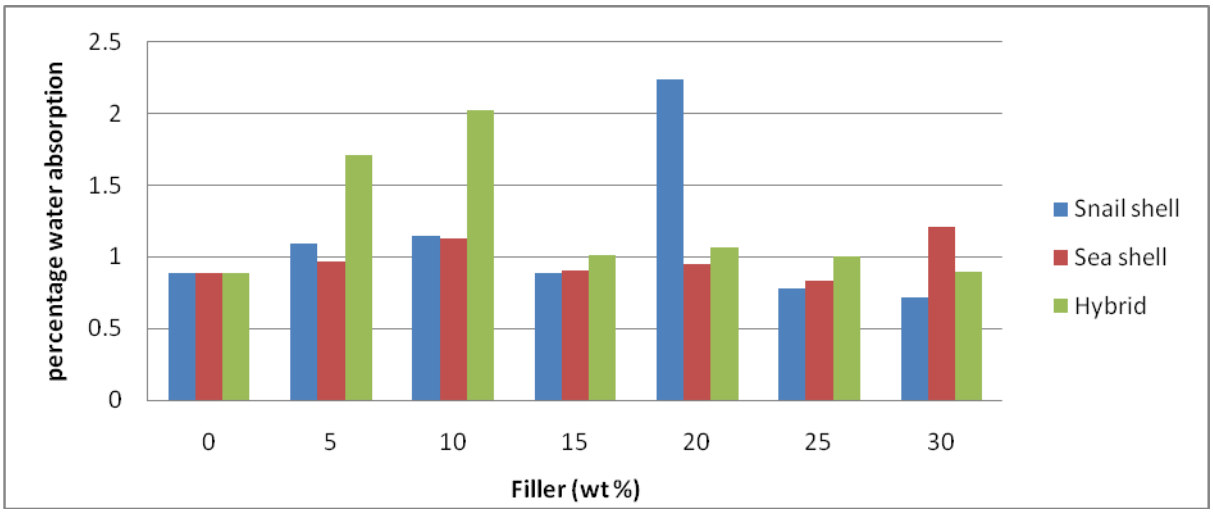

Fig 10 Chart of percentage water absorption against filler concentration

VI. CONCLUSION

The mechanical tests carried out include; flexural test, impact test, hardness test, tensile test, water absorption tests using various proportions of reinforcement. It was seen that the mechanical properties of polyester can be greatly improved by these reinforcements. From figures 4 and 5 it can be seen that the hybrid sample of 30wt% reinforcement showed the highest resistance before shattering relative to other samples the flexural test was performed on. This implies that the hybrid reinforcement of 30wt% can be used in place of the pure polyester for applications where flexibility is a major consideration. From figure 6 it can be seen that the snail shell sample of 5wt% reinforcement showed to absorb the highest amount of energy before shattering relative to other samples the impact test was performed on. Therefore, the snail shell reinforcement of 5wt% can be used in place of pure polyester where impact strength is a major concern.From figure 7 it can be seen that the hybrid sample of 15wt% reinforcement showed to have the highest surface hardness compared to all other samples being tested. This implies that the hybrid reinforcement of 15wt% can be used in place of the pure polyester for applications where surface hardness is a major consideration. From figures 8 and 9, it can be seen that the performance of all the composites being tested were very poor when subjected to tensile loading, it can be seen that tensile strength and strain of the pure polyester reduced when it was reinforced. This implies that the use of these composites should not be considered in applications that would subject it to tensile loading.
In conclusion, these composites can be used in place of pure polyester depending on the filler content and also area of application.

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